EXECUTIVE SUMMARY

1.0 Introduction

This summary is designed to serve as a stand-alone document as well as part of this report. For that reason, the reader will find some duplication of verbiage and figures between the summary and the full report. The Naval Air Warfare Center Weapons Division (NAWCWPNS) was a committed and effective partner for the Joint Advanced Distributed Simulation Joint Test and Evaluation (JADS JT&E) Joint Test Force (JTF) in the planning, preparation, and execution of the Linked Simulators Phase (LSP) of the System Integration Test (SIT).

2.0 JADS Overview

The JADS JT&E was chartered by the Deputy Director, Test, Systems Engineering and Evaluation (Test and Evaluation), Office of the Under Secretary of Defense (Acquisition and Technology) in October 1994 to investigate the utility of Advanced Distributed Simulation (ADS) technologies for support of Developmental Test and Evaluation (DT&E) and Operational Test and Evaluation (OT&E). The program is Air Force led, with Army and Navy participation. The JTF manning includes 23 Air Force, 13 Army, and 2 Navy. Science Applications International Corporation and Georgia Tech Research Institute provide contracted technical support. The program is nominally scheduled for five years.

The JADS JT&E is directly investigating ADS applications in three slices of the T&E spectrum: a System Integration Test (SIT) which explores ADS support of air-to-air missile testing, an End-To-End (ETE) test which explores ADS support for Command, Control, Communications, Computers, and Intelligence (C4I) testing, and an Electronic Warfare (EW) test which explores ADS support for EW testing. The JTF is also chartered to observe, or participate at a modest level, in ADS activities sponsored and conducted by other agencies in an effort to broaden conclusions developed in the three dedicated test areas.

Phase 1, the Linked Simulators Phase (LSP), of the SIT is the subject of this summary report.

3.0 SIT Overview

The SIT is a two phase test designed to examine the application of ADS technology in two architectures. The first phase employed an all simulator architecture which incorporated a manned F-18 avionics lab (simulator) at China Lake NAS as a shooter, a manned F-14 avionics lab (simulator) at Point Mugu as a target, and a missile hardware-in-the-loop (HWIL) simulation lab (SIMLAB) at China Lake which generated AIM-9 missile flyouts and injected countermeasures (flares). The second phase of the SIT employs an architecture which incorporates a live F-16 shooter aircraft, a live F-16 target aircraft, and an Advanced Medium Range Air-to-Air Missile (AMRAAM) HWIL simulation hosted in the Eglin AFB Guided Weapons Evaluation Facility (GWEF). This document summarizes the LSP activities.

4.0 LSP Test Plan Overview

4.1 Purpose

The LSP was designed to examine the real-time interactions between networked manned flight simulators, a missile HWIL simulation facility, and a control center. The focus of the examination was on the relationships between network performance, system under test (SUT) data, and test measures of interest. In general terms, the purpose was to collect data on the quality and usability of test data in this particular distributed test architecture. The test objectives were:

4.1.1 Objective 1: Assess the validity of AIM-9 data obtained in the LSP ADS configuration
4.1.2 Objective 2: Assess utility of LSP ADS configuration for parametric studies
4.1.3 Objective 3: Assess effect of latency on validity of test results
4.1.4 Objective 4: Assess ability of LSP ADS configuration to support AIM-9 testing
(This test objective was broken into subobjectives as follows.)
- 4.1.4.1 Subobjective 4-1: Assess capability of network to provide required bandwidth and connectivity
- 4.1.4.2 Subobjective 4-2: Assess the effects of ADS-induced errors on LSP test results validity
- 4.1.4.3 Subobjective 4-3: Assess adequacy of standard data protocols for LSP test
- 4.1.4.4 Subobjective 4-4: Assess reliability, availability, and maintainability of ADS network
- 4.1.4.5 Subobjective 4-5: Assess capability for centralized test control and monitoring

4.2 Approach

The F/A-18 Weapon System Support Facility (WSSF) at China Lake and the F-14D Weapon System Integration Center (WSIC) at Point Mugu were the shooter and target, respectively. The shooter "fired" the AIM-9 in the SIMLAB at the target which could respond with countermeasures. Runs were controlled from a test control center which ensured all nodes were ready for each run, issued start/stop directions, and processed data packets for real time analysis of system performance. Test control was exercised from the Battle Management Interoperability Center (BMIC) at Point Mugu while the JADS Joint Test Force was physically relocating. Control switched to the JADS Test Control and Analysis Center (TCAC) after their move was complete.

Information was exchanged between participants in the form of Distributed Interactive Simulation (DIS) Protocol Data Units (PDUs). Entity state data (positions, velocities, accelerations, attitudes, attitude rates) at the output node were converted from simulator format to PDUs, and reconverted at the receiving end, into simulator format. An exception was the link between the Stores Management System of the shooter, and the missile in the SIMLAB which used 1553 data bus format. The architecture is shown below.

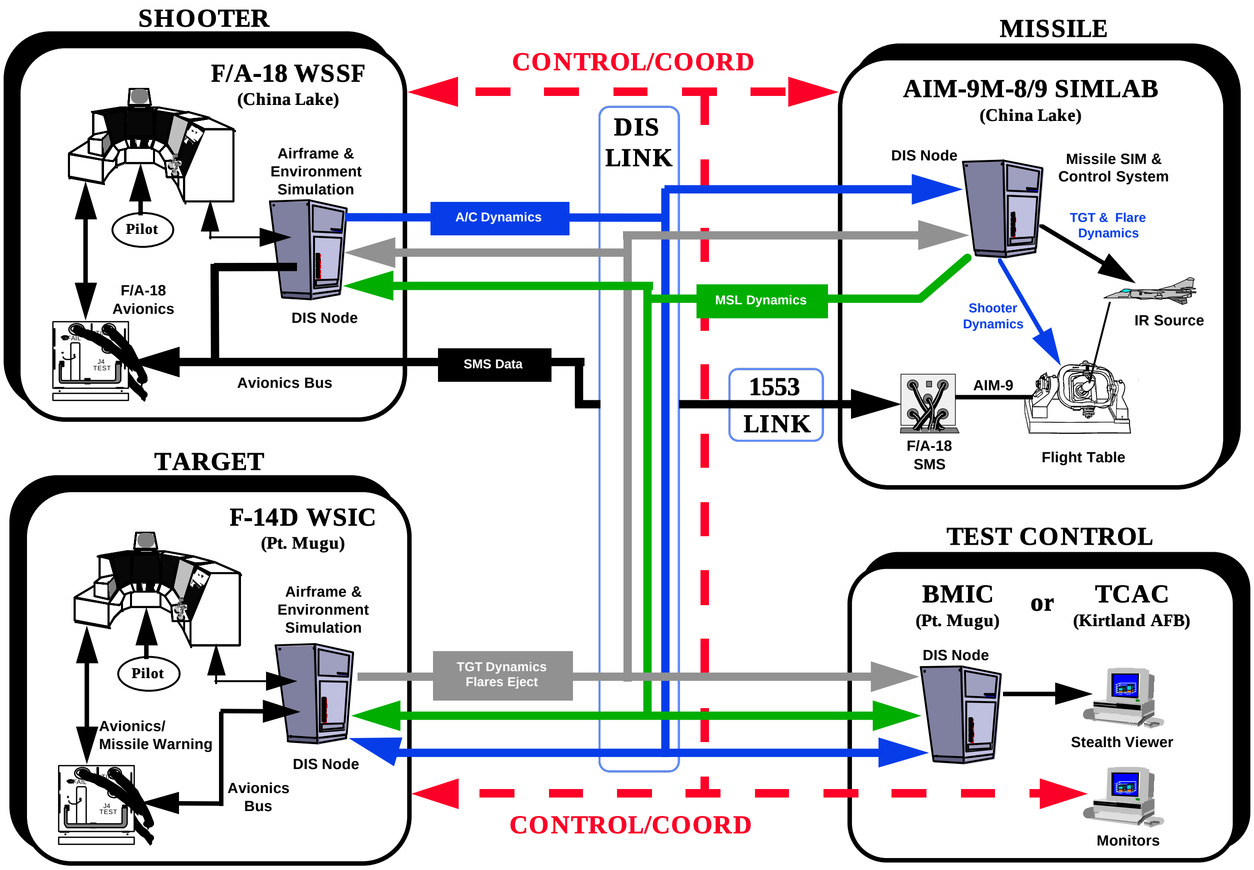

Figure ES-1. Linked Simulators Phase Test Configuration

A baseline engagement profile (LPN-15) was selected from the AIM-9M-8/9 Joint Initial Operational Test and Evaluation (JIOT&E) test series (conducted 17 May 1993 to 29 October 1993).

This single engagement geometry was the basis for all trials in the LSP. The selection of this baseline from the 16 live fire profiles of the AIM-9M-8/9 JIOT&E was based on three factors: (1) the shooter was an F/A-18, (2) flares were deployed, and (3) sufficient live fire data were available for V&V of the LSP trials. Additional details on LPN-15 are in Appendix A. The profile is depicted in Figure ES-2.

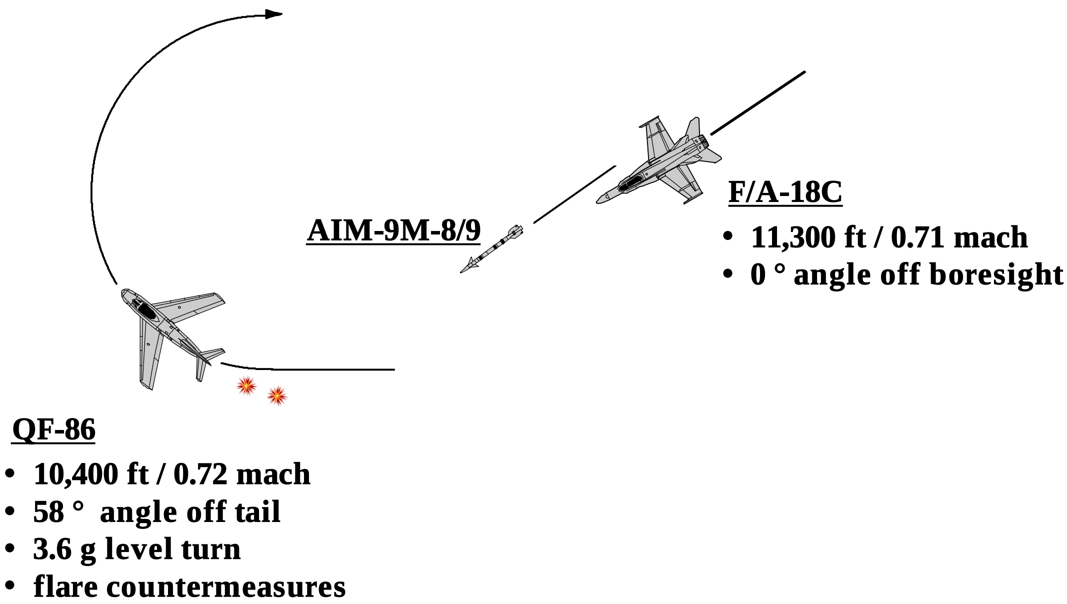

Figure ES-2. Live Fire Profile (LPN-15, 9 June 93)

The test plan scheduled three blocks of simulation "missions" as shown in Figure ES-3. The first to do Verification and Validation (V&V), the second to do parametric studies, and the third to study latency.

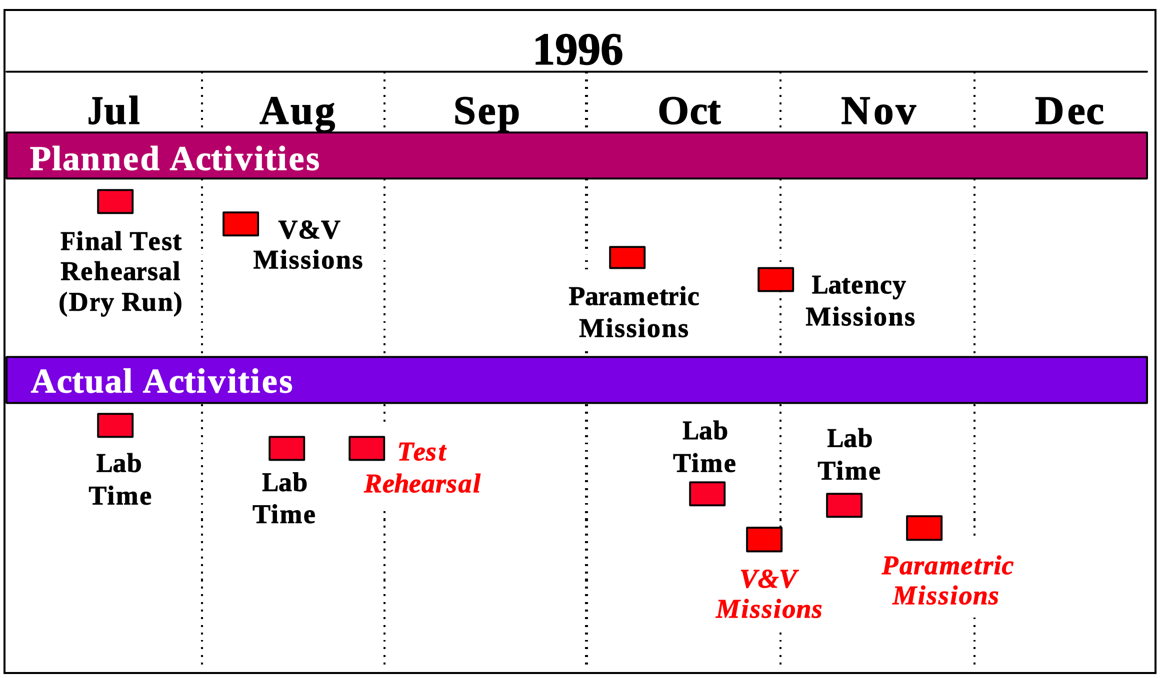

Figure ES-3. Linked Simulators Phase Test Schedule

The planned schedule is shown on the upper half of the Figure ES-3.

4.3 Instrumentation

One of the major distinguishing characteristics of a distributed testing architecture, as opposed to a distributed training architecture, is in the degree of instrumentation. The LSP architecture was instrumented to a level which supported the measurement of latency values, synchronization differences, position transformation errors, missile seeker performance, and the whole gamut of network performance measures.

5.0 LSP Test Results

5.1 Schedule

If the reader will refer to the bottom half of Figure ES-3, he will find the time lines for actual testing. The time required to integrate and check out the architecture was significantly longer than planned. Full-up architecture configurations were required to verify fixes to integration problems. (Stand-alone fixes were postulated, and tried, but most fell short when the network was reinitiated.) The periods of integrated verification work were called “lab periods”, and they moved scheduled test activity to the right on the timeline. In fact, there were still some problems at the start of execution of the V&V missions, and one could argue that we weren’t really ready to test until the Nov test. The 3 to 4 month slip was a reflection of number of things:

1. This technology is definitely not “plug-and-play” in T&E applications.
2. There is a significant learning curve for people inexperienced in establishing these architectures.
3. The learning curve applies at every node of a distributed architecture.
4. System integration is the name of the game.

If the same team of people were to construct a similar architecture now, set-up and check out would probably take a small fraction of the time experienced on this first test sequence.

5.2 V&V Missions

The underlying assumption in the approach to V&V was that JADS would quantitatively compare the representation of participant and SUT behavior in the LSP architecture with the results of the live test. The statistical reality was that we only had a single data point on the live side of the comparison, and a rigorous quantified approach was not practical. The test force fell back upon a qualitative comparison of live profiles with the ADS profiles, and found that comparison useful.

5.3 Parametric Missions

The expectation for the parametric studies was that a selected set of “best” runs, recorded during ADS testing, would be replayed in an automatic mode while selected parameters were varied in a controlled fashion. In fact, since the aircraft simulators were designed to operate with a human at the controls, there was no way to implement automatic runs. The extensive parametric activity planned for was scaled back. However, the pilots were able to achieve reasonably tight adherence to scripted profiles manually, and the test force concluded that the ADS architecture would be useful for parametric studies.

5.4 Latency Missions

The schedule slippage discussed in Par. 1.4.1 precluded execution of the Latency Study Block of LSP as originally intended. Nonetheless, the JTF collected sufficient data to support a thorough understanding of latency, and its impact on test data in this particular architecture. Latency was addressed in two components, transmission latency, and processing latency. Transmission latency is essentially the time associated with data travel through the WAN legs. That component of latency was predictable and statistically well-behaved. Obviously, transmission latency is a function of distance, but for this test the average latency on the 140 mile leg was about 20 ms. Early on, processing latencies could be as high as several hundred ms. Compared to transmission latencies, processing latencies were not as statistically well-behaved. In the later test events, while it varied from leg to leg, processing latency was about twice the magnitude of the transmission latency component.

5.5 General

5.5.1 Reliability

The reliability of the long-haul elements of the network (the Wide Area Network (WAN) was very good. The availability of the complete LSP ADS configuration was on the order of 85%. Reliability expressed in terms of successfully linked runs was about 67% over the entire span of rehearsal and test activity. Runs failed for a wide variety of reasons involving people, computers, instrumentation, data recording equipment, and simulator performance.

5.5.2 ADS-Induced Errors

ADS-induced errors, aside from latency, were tolerable. Position transform errors were on the order of two to three feet. Initially, there was a significant position divergence problem between the target position as determined by the SIMLAB and the true target location. This was caused by the manner in which the SIMLAB simulation processed the incoming target data for presentation to the seeker and by coordinate transformation inaccuracies. The errors were reduced by nearly an order of magnitude when the transformation was corrected and the PDU update rate increased. The remaining error of about 30 ft is still significant, but the problem appears solvable.

5.5.3 Test Control

Test control procedures were refined throughout the preparation process, and worked well during testing.

5.6 Fulfillment of Test Objectives

All test objectives (See par. 4.1) were met.

6.0 Lessons Learned

6.1 Technical

The test team, and the system experts from each node, need ready access to experts in data transformation and interface software.

Synchronization of activity in a network is difficult. Not every processing element in a distributed architecture has direct access to GPS time, so a "master clock" has to be built into the architecture.

Commonality of ADS hardware and software is necessary. Routers from different vendors may, or may not, interoperate efficiently. Supposedly interoperable software may not work as advertized --- carefully review version numbers.

Understand before designing a distributed architecture what the latency requirements are. Incrementally build to satisfy them.

Special test instrumentation and tools are required to support distributed T&E. The tool set must support rapid identification and characterization of network problems and time tagging of data elements sufficient to support analyses.

6.2 Infrastructure and Process

ADS requirements must be developed early, understood by all parties, and thoroughly documented. The communications required to exercise test control must be identified early.

SUT experts must be involved from the outset.

The architecture build-up must be incremental, beginning with check out of the ADS elements in a stand-alone mode, and evolving, step by step, to the fully integrated configuration.

Problem solving/fixes frequently require verification in a full-up network environment.

Detailed planning for data management is a necessary precursor to testing.

Contracting to support ADS should most often be on a cost plus basis. There are too many unknowns to make fixed price contracting a viable option.

Centralized test control processes have to be integrated with established local processes and procedures.

Configuration control in a distributed architecture is difficult, but essential. The test organization needs to be represented at each test architecture node.

7.0 Conclusions

This particular test architecture would not support valid closed-loop interactions between the missile and target. It could support closed-loop interactions between the shooter and the target for such purposes as test rehearsal. A similar architecture with more representative (realistic) flight simulators could probably support tactics development and training.

With more attention, and more time, better NIUs could have been developed, and better NIUs might improve accuracies and latencies, and ease synchronization difficulties.

Preparation, set up, calibration, and check-out activities are more challenging and time consuming in a distributed environment. The time lines from this particular test, however, should be viewed with caution. The technology's use in T&E is still in its infancy, and the test agencies involved in the integration activities are climbing a steep learning curve. If another tester were to work with China Lake and Pt. Mugu, we believe the preparation time lines would be considerably shorter that they were the first time.

The development of a distributed T&E architecture is not a "plug-and-play" exercise. In the near term, the elements available for linking in a given architecture, were almost certainly not designed to be linked. That means that the burden for making linked architectures work falls upon the interfacing and integrating activities. The NIUs, the translation software, the geographical transforms, etc. are the interface components which allow distributed systems to function with existing players today.